Seasonal Anomalies of Temperature and Salinity in the Northwest Atlantic in 1983

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Les rapports techniques peuvent être considérés comme des publications à part entière. Le titre exact figure au-dessus du résumé du chaque rapport. Les résumés des rapports seront publiés dans la revue Résumés des sciences aquatiques et halieutiques et les titres figureront dans l'index annuel des publications scientifiques et techniques du Ministère.

Les rapports techniques sont produits à l'échelon régional mais sont numérotés et placés dans l'index à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page de titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Les établissements des Sciences et Levés océaniques dans les régions et à l'administration centrale ont cessé de publier leurs diverses séries de rapports depuis décembre 1981. Vous trouverez dans l'index des publications du volume 38 du *Journal canadien des sciences halieutiques et aquatiques*, la liste de ces publications ainsi que le dernier numéro paru dans chaque catégorie. La nouvelle série a commencé avec la publication du Rapport n° 1 en janvier 1982.

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Abstract

The production of a digital atlas by Levitus (1982) has permitted the ready comparison to observations collected in the Northwest Atlantic during 1983. The atlas has values for temperature and salinity calculated at each degree of latitude and longitude and seasonally. Using this atlas, the available 1983 temperature and salinity observations at four depths in the North Atlantic were converted to anomalies. Maps of these anomilies have been generated for each of the four seasons of 1983, using the optimum interpolation technique. This provides the added benefit of estimates of the errors in the mapping of the anomalies. The results are compared to other studies and show overall agreement although there are some areas of dispute.

Résumé

En 1982, Levitus a créé un atlas numérique permettant de comparer des observations de température et de salinité recueillies de l'Atlantique nord-ouest en 1983. La comparaison peut être faite pour chaque degré de latitude et de longitude, à quatre profondeurs et pour chaque saison. Des cartes d'anomalies pour ces variables ont été générées en employant la technique de l'interpolation optimum. On réalise ainsi des estimés d'erreurs des anomalies. Les résultats sont comparés à ceux d'autres études et ils sont généralement en accord bien qu'il y ait quelques points en désaccord.

INTRODUCTION

Early after its inception, ICNAF (now the Northwest Atlantic Fisheries Organization, NAFO) recognized the need for standard data sets to provide a basis of comparison in attempting to quantify variations in the physical environment of the ocean. To this end, it recommended a series of standard stations along sections at which observations should be acquired if ships of member states were in the area (ICNAF 1976, ICNAF 1978) It also recommended baseline periods and calculation techniques so that all members might use a common reference for discussions of changes in the ocean environment (ICNAF 1976, NAFO 1983).

While the concept of standard stations, sections and baselines is useful, in the case of the NAFO area, the volume of data available is still so limited that meaningful calculations are difficult to make, apart from a few exceptional cases (Keeley 1981, Keeley 1982). The failing is due primarily to the relatively short period over which these recommendations have been in place and the usual problems of making observations at sea at all times of year.

To bypass the problems of data paucity, scientists often choose to treat data from areas and over time spans rather than point observations. Doing this, automatically invokes the standard oceanographic assumptions of synopticity and ignores variability at scales smaller than the areas treated. While these studies are worthwhile, they have lost the intercomparability by replacing the agreed upon baselines by their own.

Each year at its annual June meeting, the Environmental Subcommittee of NAFO considers the various available papers presenting results of studies of the physical oceanography conducted in the NAFO area during the previous year. The goal is to arrive at some overall description of the conditions extant through the year. Some of the papers present analyses of results from the past year only. Many of the papers present results which are regional in scope. Some of these, make only qualitative comparisons to previous years. Others, particularly in the past few years, attempt by various schemes to quantify the relationship between the present and past years. These studies proceed using whatever data are available and techniques deemed by the scientist to be the most useful. Many of the results have been interesting but difficult to intercompare because of the lack of a common basis.

In 1982, Levitus published an atlas of temperatures and salinities for the world ocean (Levitus 1982). While his is not the first to present such information, it was the first to provide the data in computer compatible form. For the first time, anyone with a computer could purchase an atlas, and choose to look at the information in any fashion, not just at the displays of the atlas. The result is that data may be readily compared to this atlas and the calculation of departures from the atlas are easily done. In effect, Levitus has presented the oceanographic community with a new baseline for problems which permit calculations at time and space scales at or larger than those of the atlas.

Once departures from the Levitus atlas are calculated it is of some interest to compare these to other work. One reason to do this is to determine if there are significant differences between the results. These differences may be the result of the differing analysis techniques or the differences in the data available to the calculation. In this latter event, differences in results begin to illustrate aliasing problems due to inadequate sampling of the oceanic variability. There is an organization in the United States which regularily publishes analyses of surface temperature data only. This is the Oceanographic Monthly Summary (hereafter referred to as OMS) published by the U.S. Department of Commerce (US Dept. of Commerce). Each month, anomalies of sea surface temperature for the north Atlantic and north Pacific oceans are portrayed. These are based on all data at their disposal but the data coverage is not indicated on the maps nor in the text.

It was considered that the existence of the Levitus atlas may provide the necessary baseline data which would permit an analysis of yearly data to derive anomaly charts not only at the sea surface and for temperature but also at depth and for salinity. These analyses have been in demand for some time but no clear way of providing reliable estimates was known. The results presented here are the first attempt to generate anomaly charts for the NAFO area. Because the data in the atlas are at 1 degree intervals of latitude and longitude and the data are represented only seasonally, this is the space and time resolution that has been used in the analysis.

INITIAL DATA PROCESSING

All of the data which exists in MEDS files from 1983 was used in these analyses. This was composed of observations collected using either water bottles or bathythermographs.

Some of the data were received via the Global Telecommunications System in an IGOSS format.

Data received this way and by the more conventional data exchanges were compared to remove duplicated stations. In total there were about 7600 temperature and 2500 salinity observations used. These were spread over all months and at 4 depths. Since this was a trial of the analysis procedure, contours of anomalies were generated at 0, 100, 250 and 500m only. These depths were chosen to represent surface conditions, those on continental shelves and deeper levels from mid-oceanic observations. For the two variables separately, there were roughly equal numbers of observations in each of the four seasons although observations of salinity were relatively more plentiful in autumn and winter. Surface observations constituted more than half of the total number available in any season and depth.

While it is a straightforward procedure to calculate maps of temperature or salinity, anomaly maps of these variables are of more interest. This is because it is much easier to judge the characteristics of a year by examining the departures from some baseline rather than the values themselves. Computationally, there are some advantages in calculating the anomalies. In order to derive an anomaly given an observed temperature or salinity at an oceanographic station, it is necessary to subtract from it the climatic values at the given station, depth and time. It was possible to use the values in the atlas directly at the selected depths and bi-linear interpolation was used within one degree squares to derive the climatic conditions at station positions. However the seasonal sampling of the climatology is rather coarse and caused some difficulties. For example, if linear interpolation between seasons is used, then the amplitude of the fundamental yearly cycle may be reduced by up to 30%. As well, the three month averaging of the climatology acts as a smoothing filter and reduces the amplitude by a further 10%. Since the temperature may vary by as much as 18 degrees over one year at some locations in the NAFO area, it is obvious that significant anomaly errors may be anticipated.

To get some idea of the extent of the trouble, some sample anomaly contour plots were produced using four different interpolations of the atlas data in time. The four types were:

a) Zero order interpolation. The atlas value nearest the date of the observation was used directly.
b) Linear interpolation between seasons.
c) Fourier fit through the four seasonal atlas values. This includes the mean, the yearly cycle and the cosine portion of the six month cycle.

d) Corrected fourier fit. This is the same as c) but with the wave amplitude scaled up by 10% to compensate for the seasonal smoothing.

The sample plots showed differences due to the various interpolation schemes. However, the main features in the regions where there was good data coverage were quite stable. Because of this, and because scheme d) appears to be the most logical, this one was used in the final analyses. As a further test, the amplitude of the six month cycle was compared with that of the yearly cycle at a fairly large number of positions. It was found that the ratio of the six month to twelve month cycle was small almost everywhere, indicating that no serious aliasing was being introduced.

DATA ANALYSIS

Contour plots of the temperature and salinity anomalies in the Northwest Atlantic for 1983 were produced and are shown in figures 1 to 32. The plots are at depths of 0, 100, 250, and 500m. and are by season. The four analysed seasons extend from February, 1983 to January, 1984, to match Levitus' definitions of seasons in the ocean. The winter is from February to April, spring from May to July, summer from August to October and autumn from November to January. Each value in the atlas is an average of all values available within the three month period at each location and depth.

The anomalies of each observation with respect to the atlas value were calculated as described before. The anomalies are generally noisy and irregularily spaced. It is valuable to have some technique for smoothing out the noise and interpolating to get the anomaly field sampled on a regular grid. Optimum interpolation (OI) was used to do this (Bretherton, Davis and Fandry 1976, Bretherton and McWilliams 1980). Provided the noise variance and the spatial covariance of the anomaly field are known, OI will give the best possible estimate of the true anomaly field given the data available to control the interpolation. In addition, it supplies the expected error in the anomaly field at every point. This is useful in assessing the reliability of the results.

The biggest problem in applying OI to the present anomaly data was to estimate the noise and the spatial covariance function. The following form was used for the covariance between anomalies separated by the distance,R, in kms.

$$C(r) = (V-E)\exp[-.5(r/Rs)^P]$$

where the four parameters V, E, Rs, p need to be estimated. V is the variance in the field including noise, E is the variance of the noise of the data, Rs is a correlation scale length and p is an exponent.

Experimental covariance curves were generated for each the seasons, variables and depths using the given data. The four parameters defining C(R) were estimated by a least squares process in each case. Because of the uneven scatter of the data and its sparseness in certain cases, (particularily at 250 and 500m) there was guite a bit of fluctuation in the found parameter values. Any trends in the parameters due to season or depth were hard to see, though temperature and salinity gave distinctly different results. In these circumstances it seemed best to use one average set of the four parameters for temperature and another average set for salinity. The values are as follows:

Temperature anomaly	3.0	1.5	125 km	1.8
Salinity anomaly	0.6%.	0.3%.	125 km	1.8

It should also be noted that all observations giving temperature anomalies greater than 10 degrees C and salinity anomalies greater than 2 PPT were ignored in an effort to eliminate gross errors.

RESULTS

An oblique stereographic projection was used as the base map for the plots and the interpolated anomaly fields were sampled on a square grid at a spacing of about 1 degree of latitude which matches the resolution of the Levitus atlas. This spacing is too coarse to allow certain details to be resolved, especially around Nova Scotia and in the Bay of Fundy. But it is roughly the same as the correlation scale.

The temperature anomaly is contoured at 0, +/-1, +/-2, +/-4, +/-6 and +/-8 degrees.

The regions of anomalies are shaded by horizontal lines. Where the expected error of the anomaly field exceeds 2.5 degrees, the shading and contour lines are omitted. The finely spaced horizontal lines show regions where the expected error is less than 1 degree. Regions of positive anomaly are similarily indicated by coarsely and finely spaced vertical dashed lines. The salinity anomaly is contoured at 0, +/-0.2, +/-0.5, +/-1.0 and +/-1.5 PPT and the two levels of the expected error are 0.2 and 0.5 PPT.

Because of the broad averaging used to get the noise and covariance, the expected error information in the plots should not be considered exact. However, it does indicate

areas where there is good data coverage and where anomalies can be seen to be significantly different from 0.

An examination of the displays reveals some notable features. First of all, there is the tendency for warm anomalies to be associated with saltier ones and colder anomalies with fresher ones. Secondly, the features which are of substantial size and which persist over time tend to show at all of the depths presented. Some persistence is seen in the features, but substantial changes from one season to the next are also evident. The reliability of the 0 anomaly contour in each case should be judged taking into consideration the error map. While this allows a considerable freedom in locating this contour, the error calculation suggests that the data sampling is such that this is the best that can be done in specifying its position. The same consideration should be exercized when examining the other contours as well. If the anomaly exceeds the errors, then it is likely that it is real and at least as large as the difference from the error. If this is not satisfied, then the most conservative interpretation of the maps would doubt the absolute size of the anomaly as represented.

A comparison to the monthly sea surface temperature anomaly maps shown in the OMS proves to be interesting. The data set used to compile the OMS maps is not described in the publication. Also not described is the climatic data used in the computation of the anomalies. It is certain though, that the set of observations used are different, and it seems likely that the climatology is also different. With these differences it is not surprising that the results are also different. In fact, some of the differences are such that where these maps present a cold anomaly, those of the OMS show a warm one. In broad features, the two presentations are similar.

There are a number of reports presented at the 1984 meeting of the Environmental Subcommittee of NAFO which discuss the physical environment of the NAFO area during 1983. As discussed earlier, these all use differing techniques to attack the problem. A common analysis is to choose ocean areas, and to average all available data from these areas over certain time frames. A report by Trites and Drinkwater (1984) looks at a wide variety of data including wind, wave and atmospheric information as well as oceanographic observations. They subdivide the Northwest Atlantic into more than 20 areas and compute average monthly sea surface temperatures from all available data. Anomalies relative to the 1972 to 1980 period are calculated and displayed as to whether it is positive or negative. Their subdivision of the coastal region near Nova Scotia and south is so fine that it is difficult to make a comparison to the

results here. There appears to be correspondance in the region of Cape Farewell (see also Stein and Buch, 1984) and offshore of Nova Scotia. There is also some agreement near Station 27 off of Newfoundland (Chumakov, Borovkov and Noskov, 1984). The results here disagree in the region of the Gulf of Maine and to the south.

A second paper by Trites, McLain and Ingham (1984) shows more detail from the more southern regions of the NAFO area. Their results, summarized in their figure 4, present a more complete picture for 1983, and with a different threshold in the definition of an anomaly. The strong warm anomaly reported by them in the region of Newfoundland is also represented in the results here except in the autumn. At this time, the temperature anomaly is only marginally cold. The cold anomalies reported near Cape Cod early in 1983 also are represented here except these results suggest the cold conditions last longer into the year. The warm conditions on Hamilton Bank are either unrepresented here, or are reported to be cold.

SUMMARY

The production of a digital atlas by Levitus provides a common baseline to be used in the intercomparisons of separate sets of observations from the Northwest Atlantic. Making use of this, and the technique of optimum interpolation, it is possible to calculate anomalies of temperature and salinity seasonally and at a variety of depths. The depths presented here are for example only and may not satisfy the requirements of fisheries scientists in their attempts to understand the influence of the environment on the fisheries. Nevertheless, the results are of some use in assessing the state of the ocean in the NAFO area in 1983. Comparisons to the results generated by other scientists shows that many of the large scale features are commmon. There are differences in some regions and these are no doubt a reflection of the different data sets and climatologies employed in the calculations as well as the calculation techniques used to generate the anomalies.

ACKNOWLEDGEMENTS

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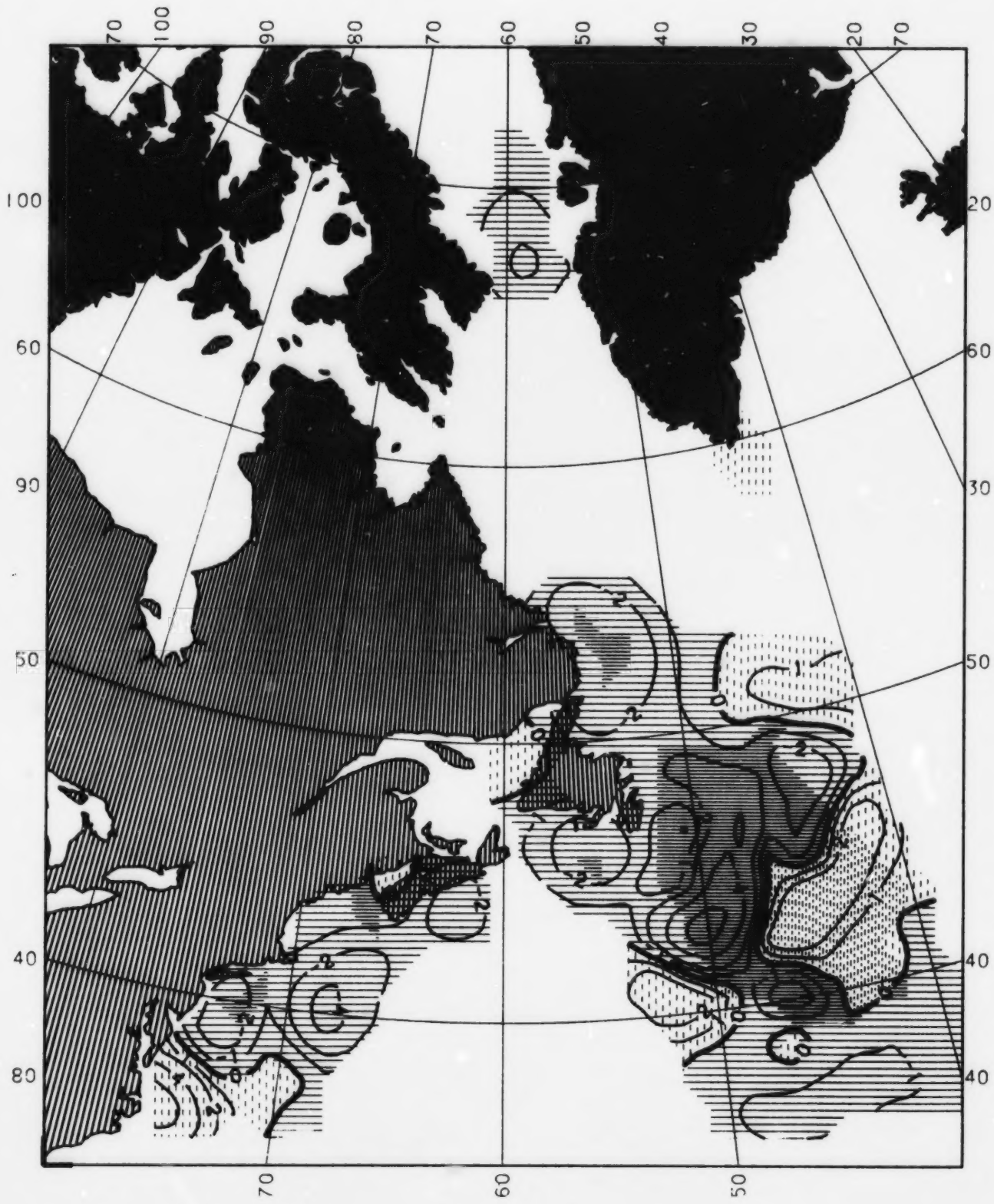
FIGURES



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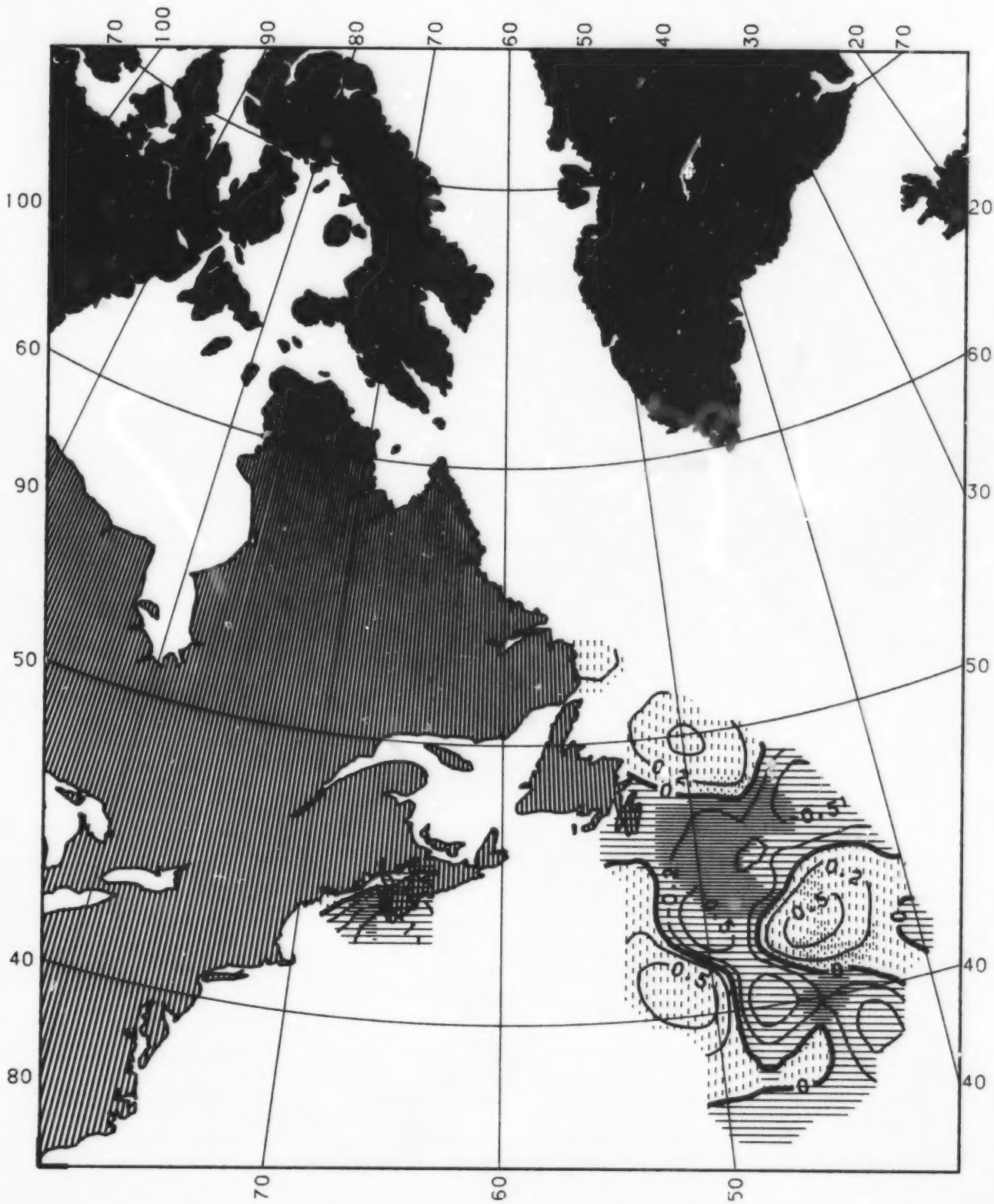

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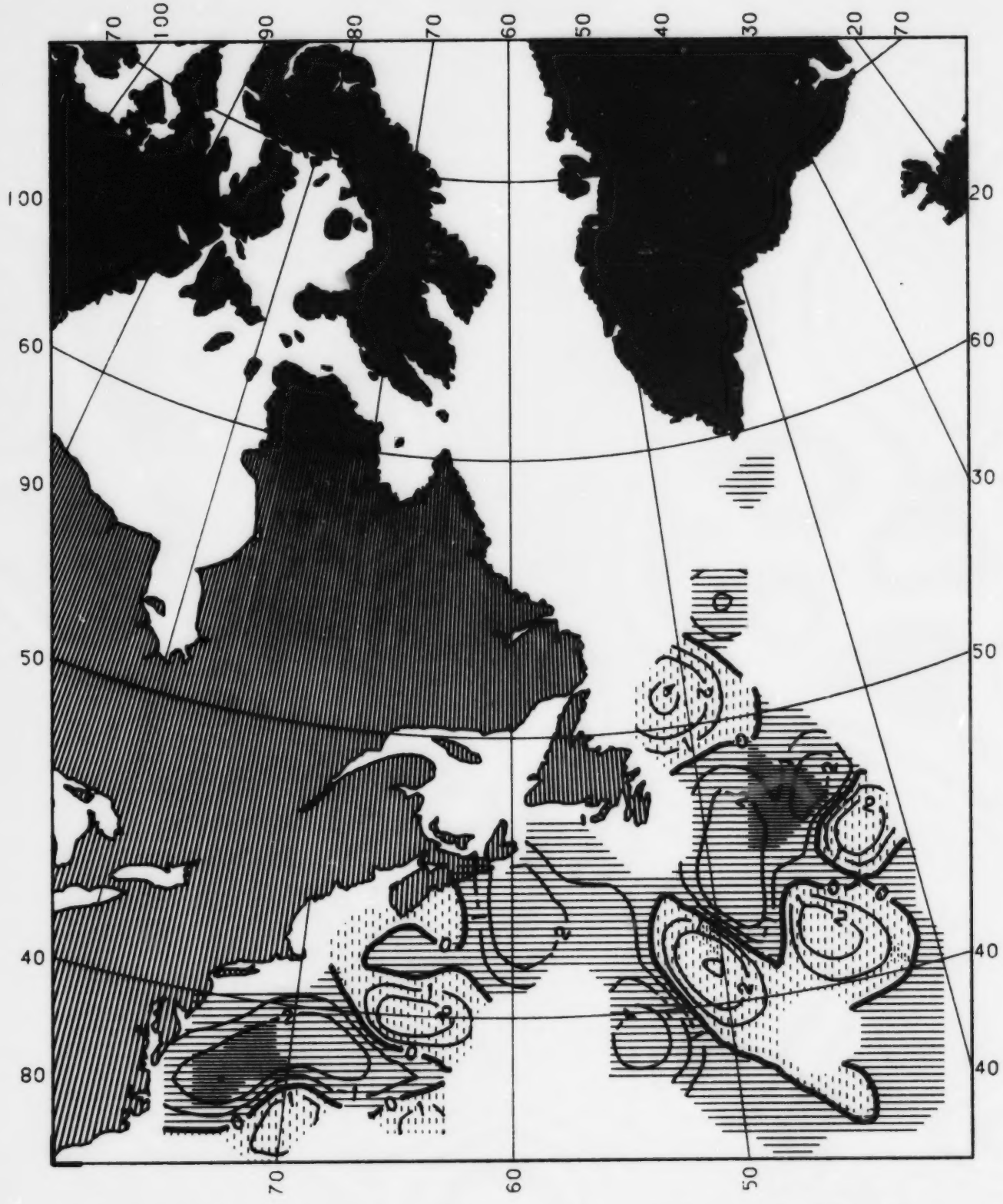

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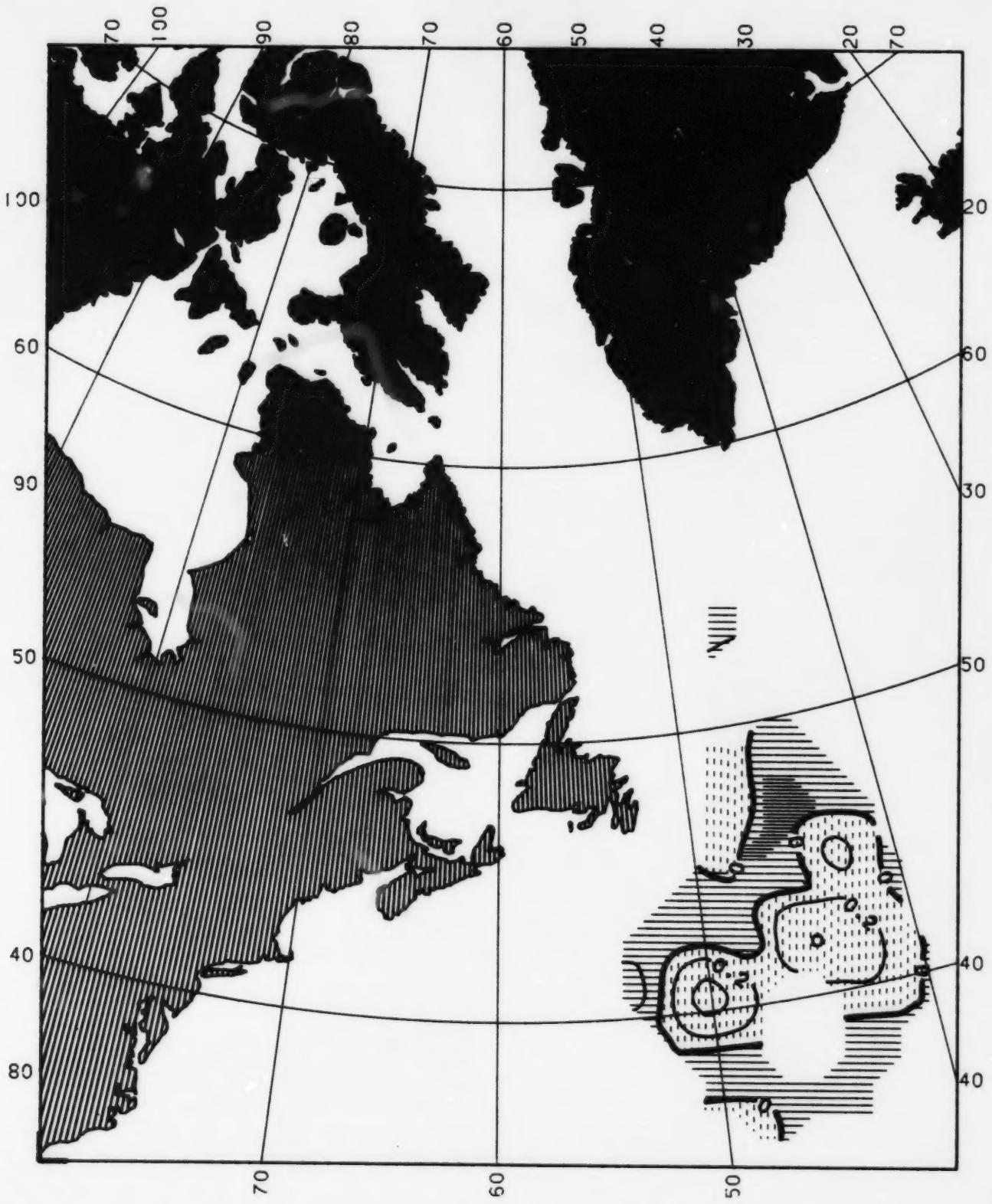

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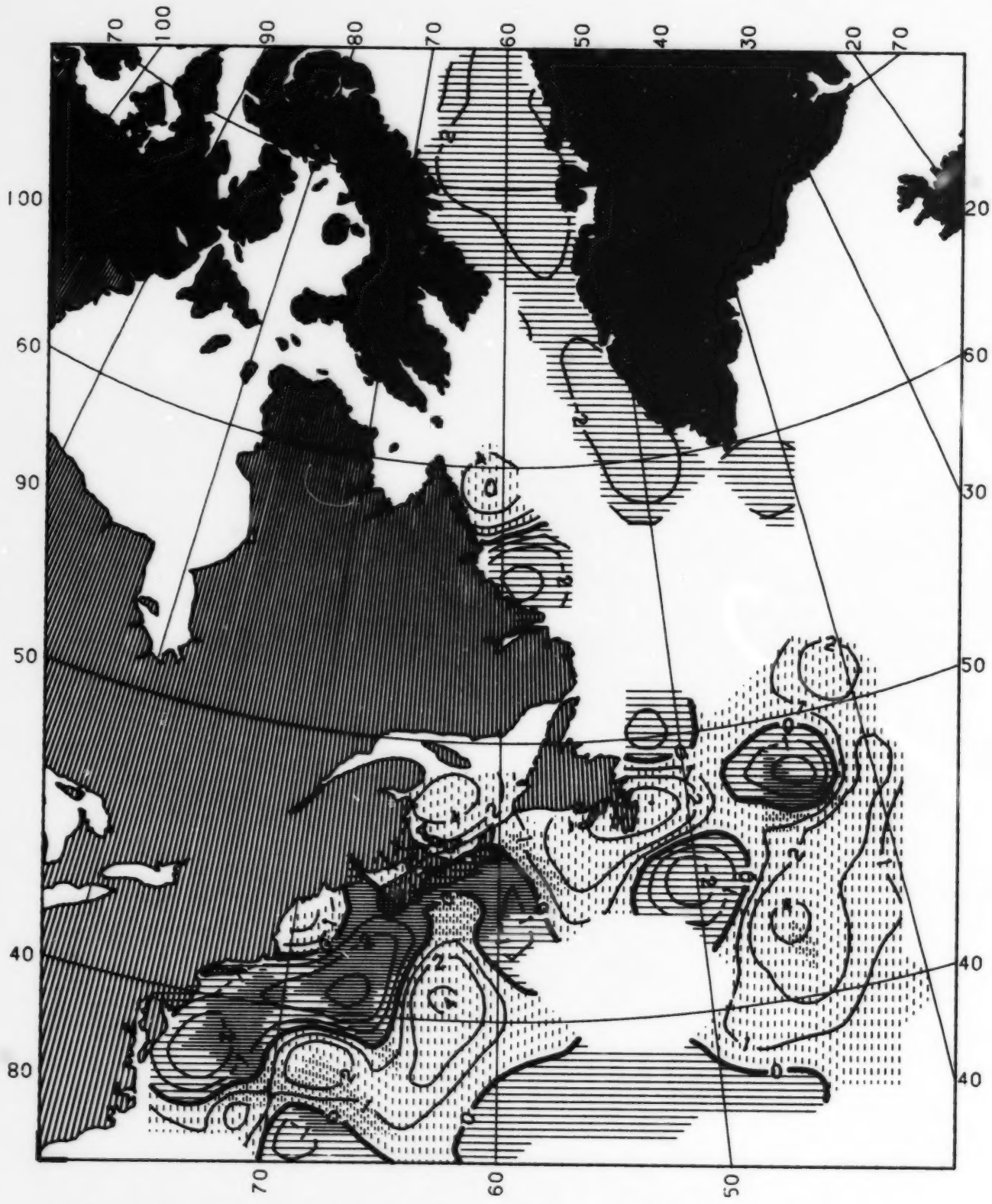

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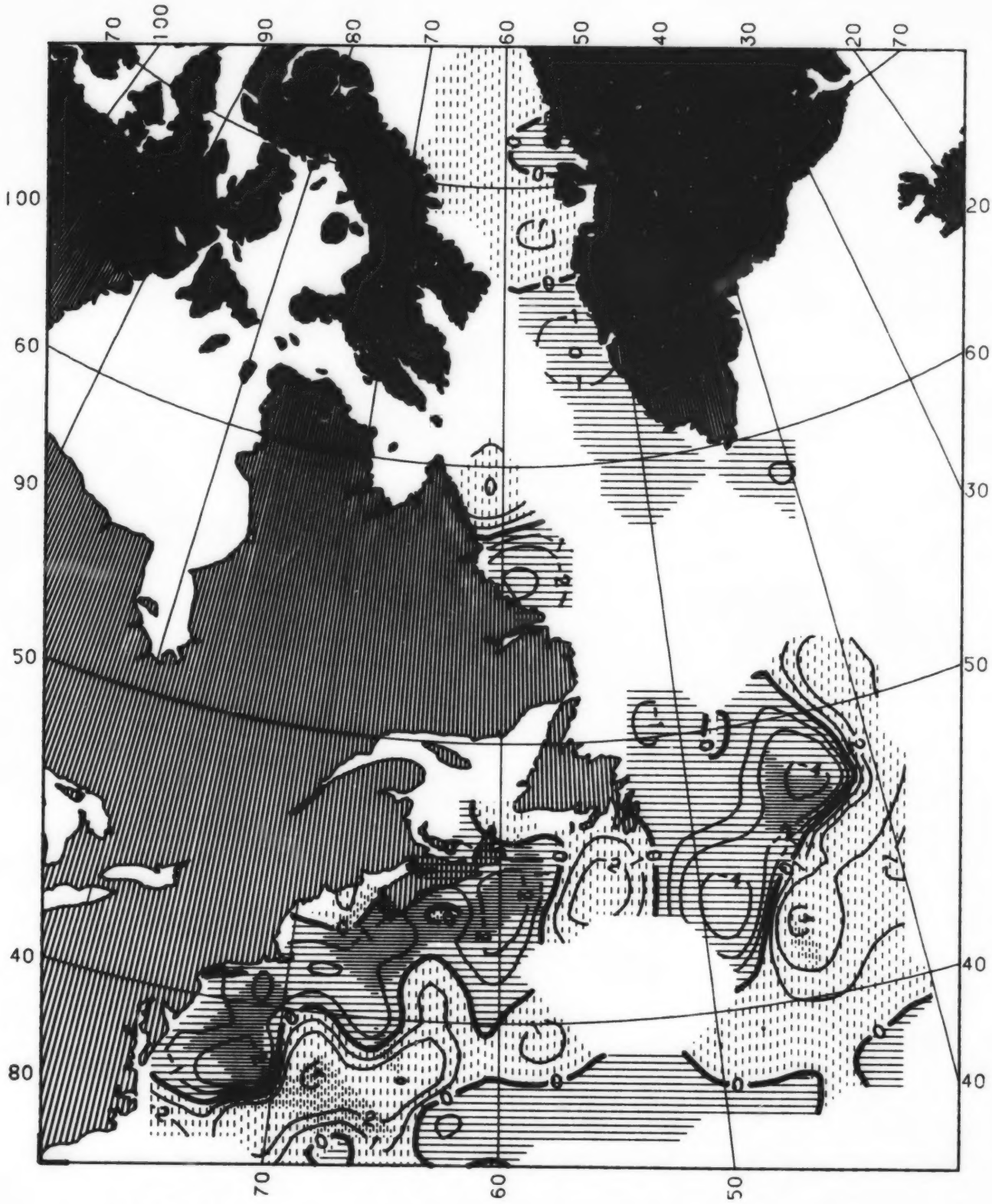

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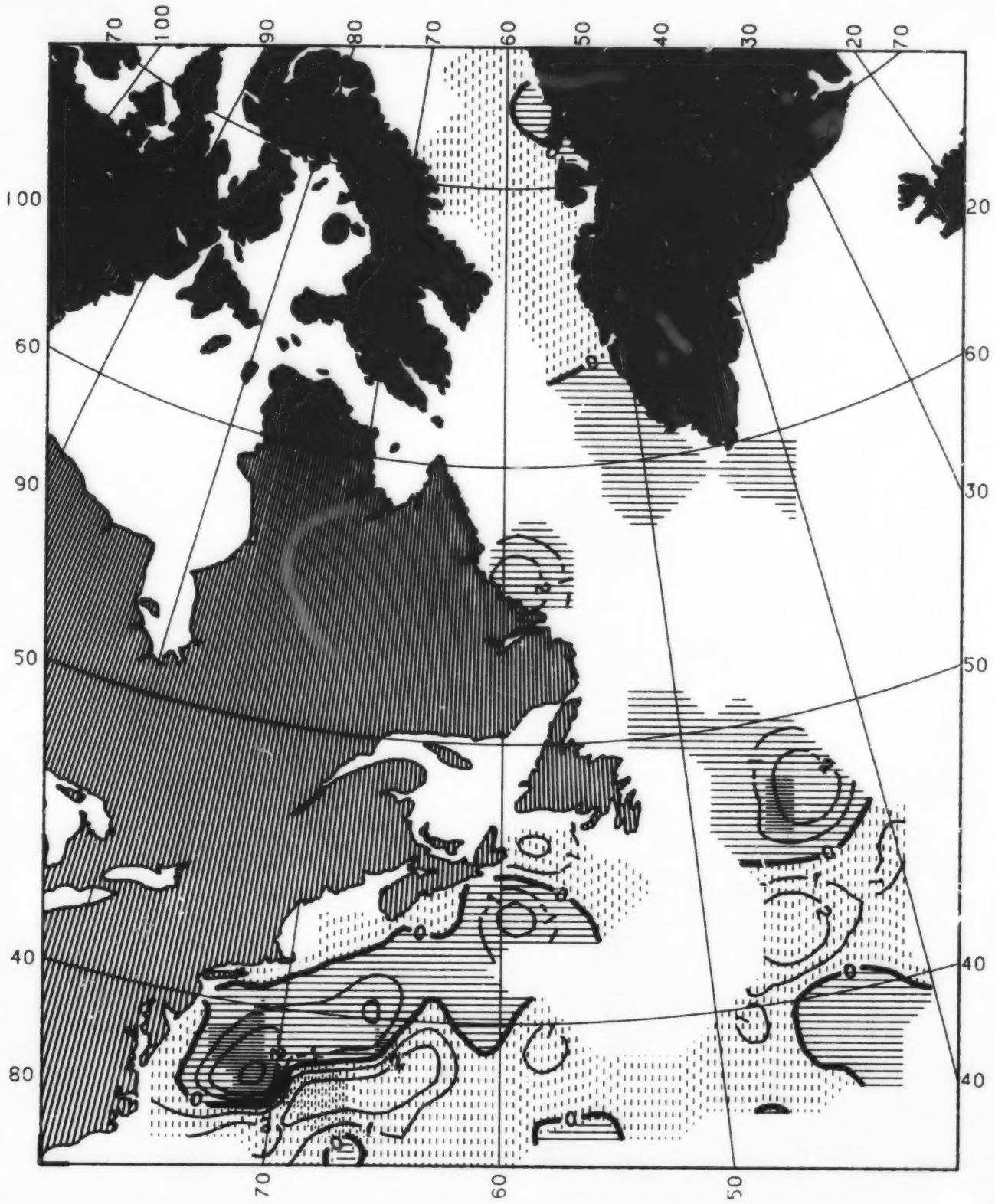

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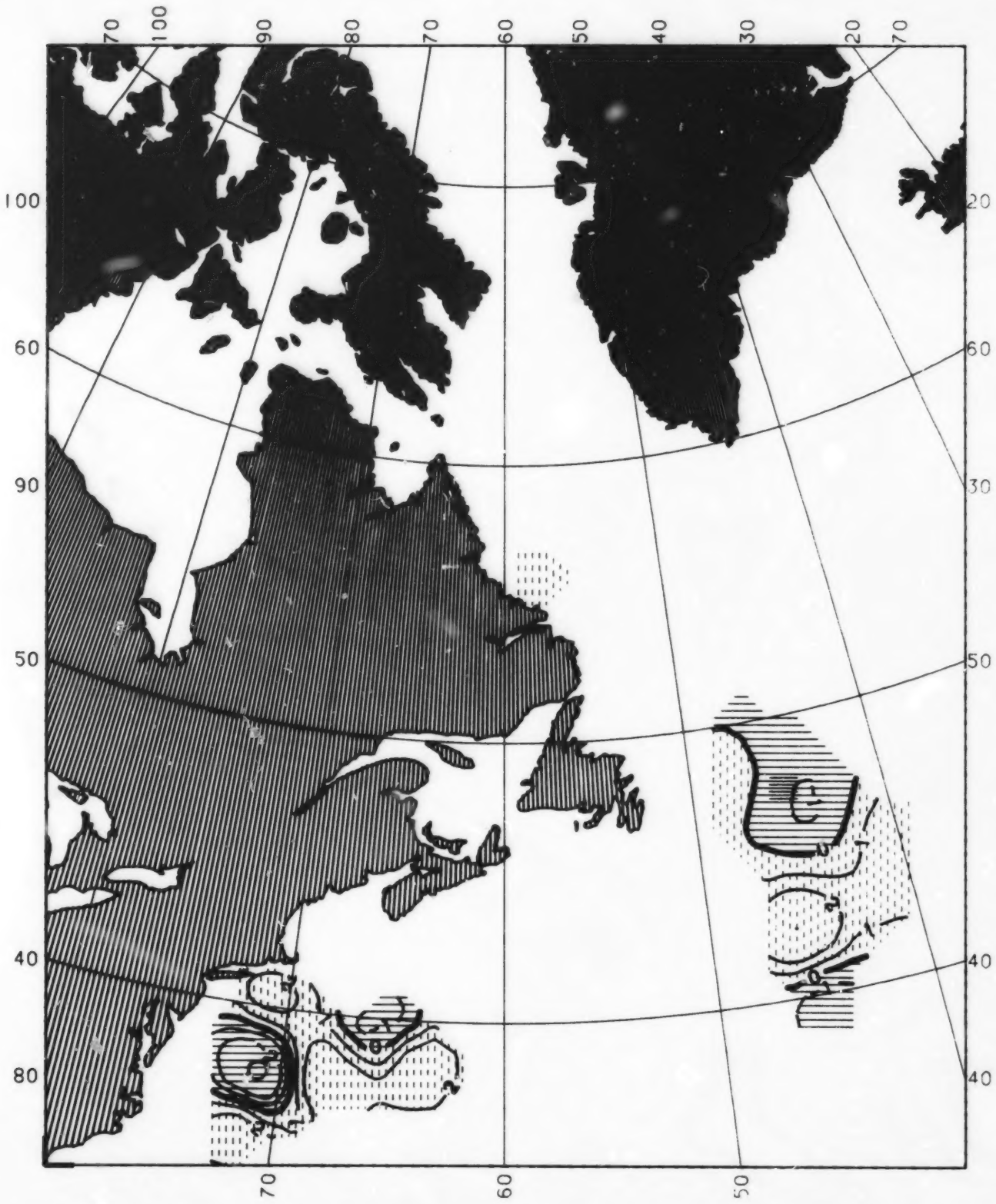

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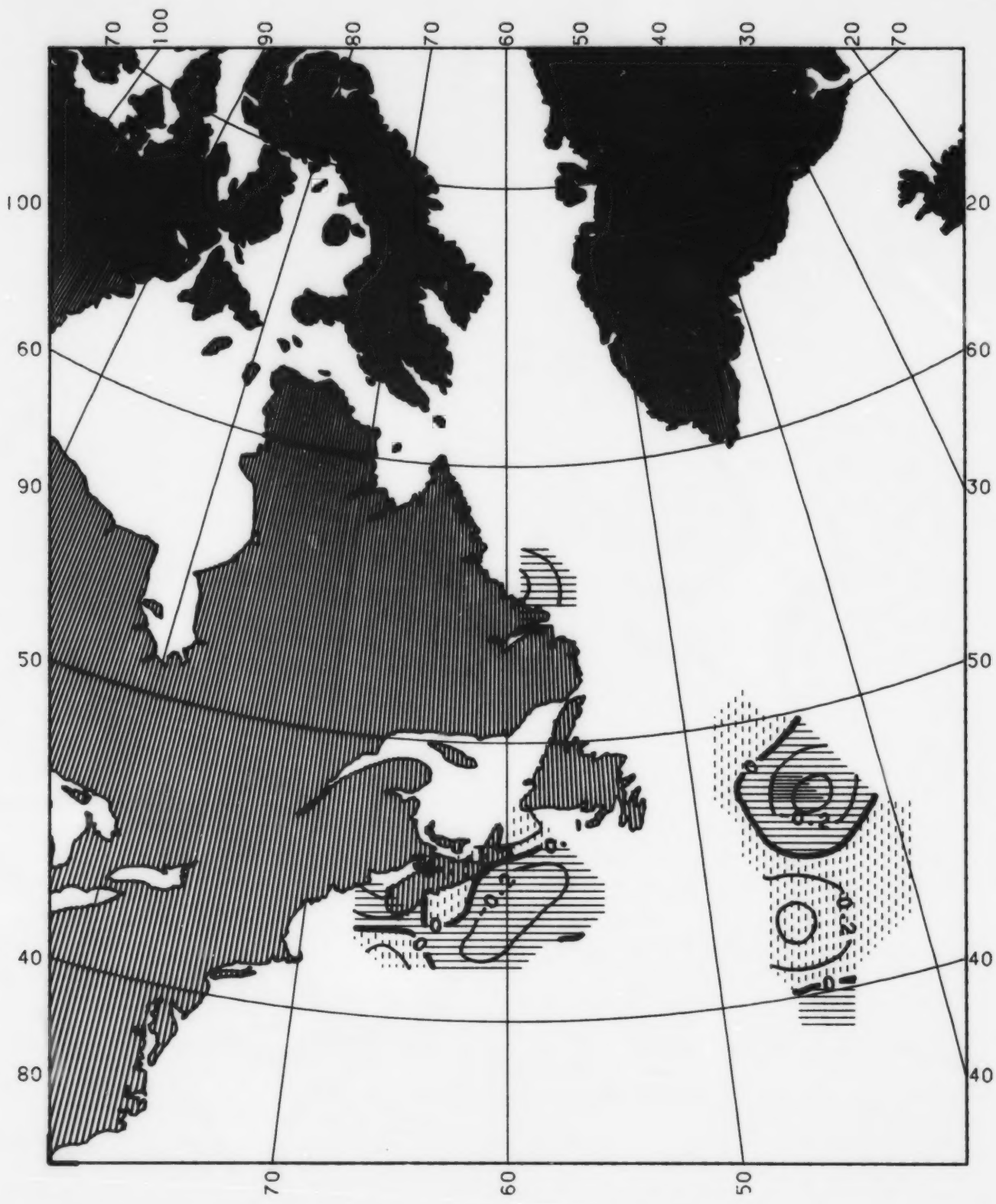

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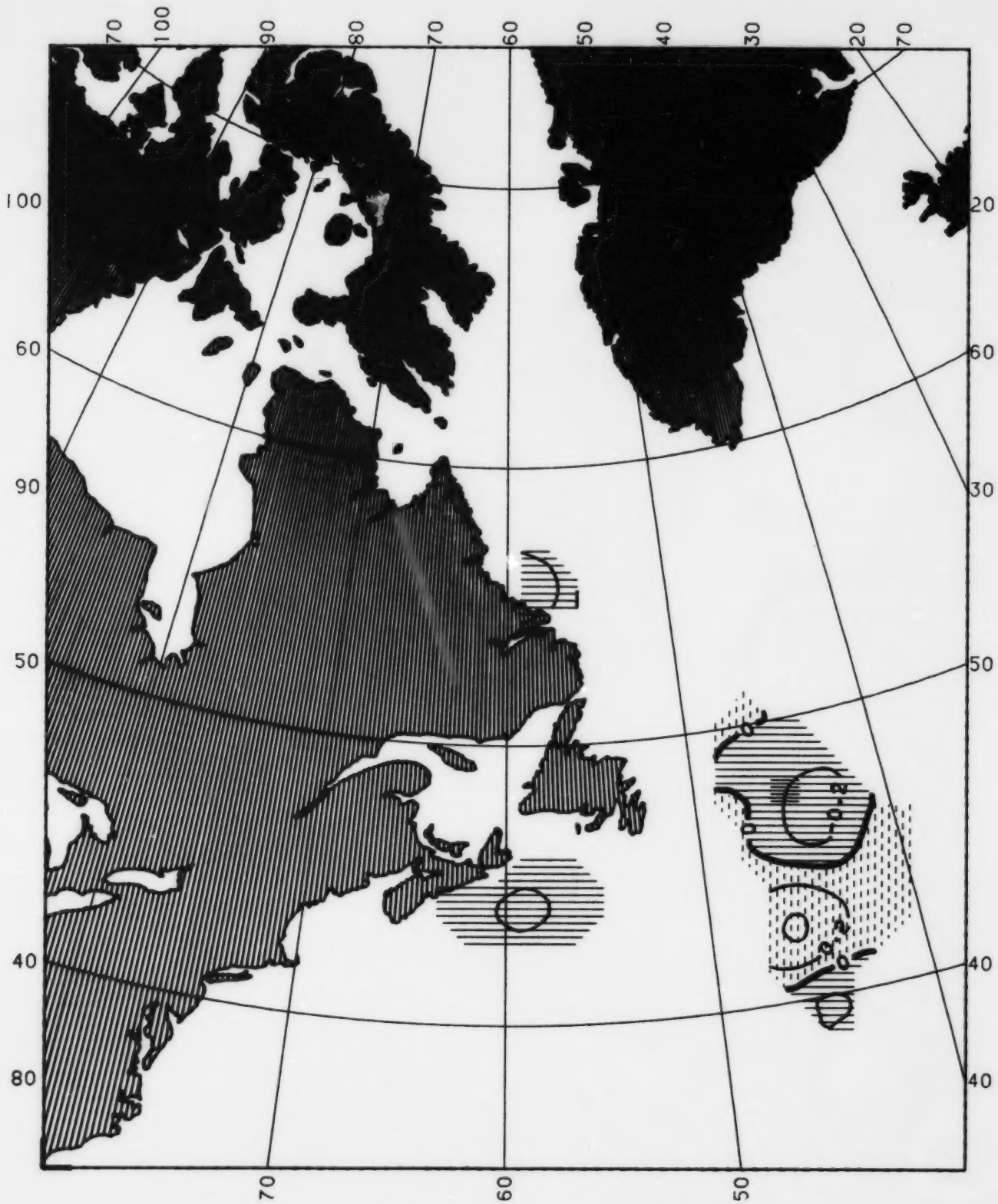

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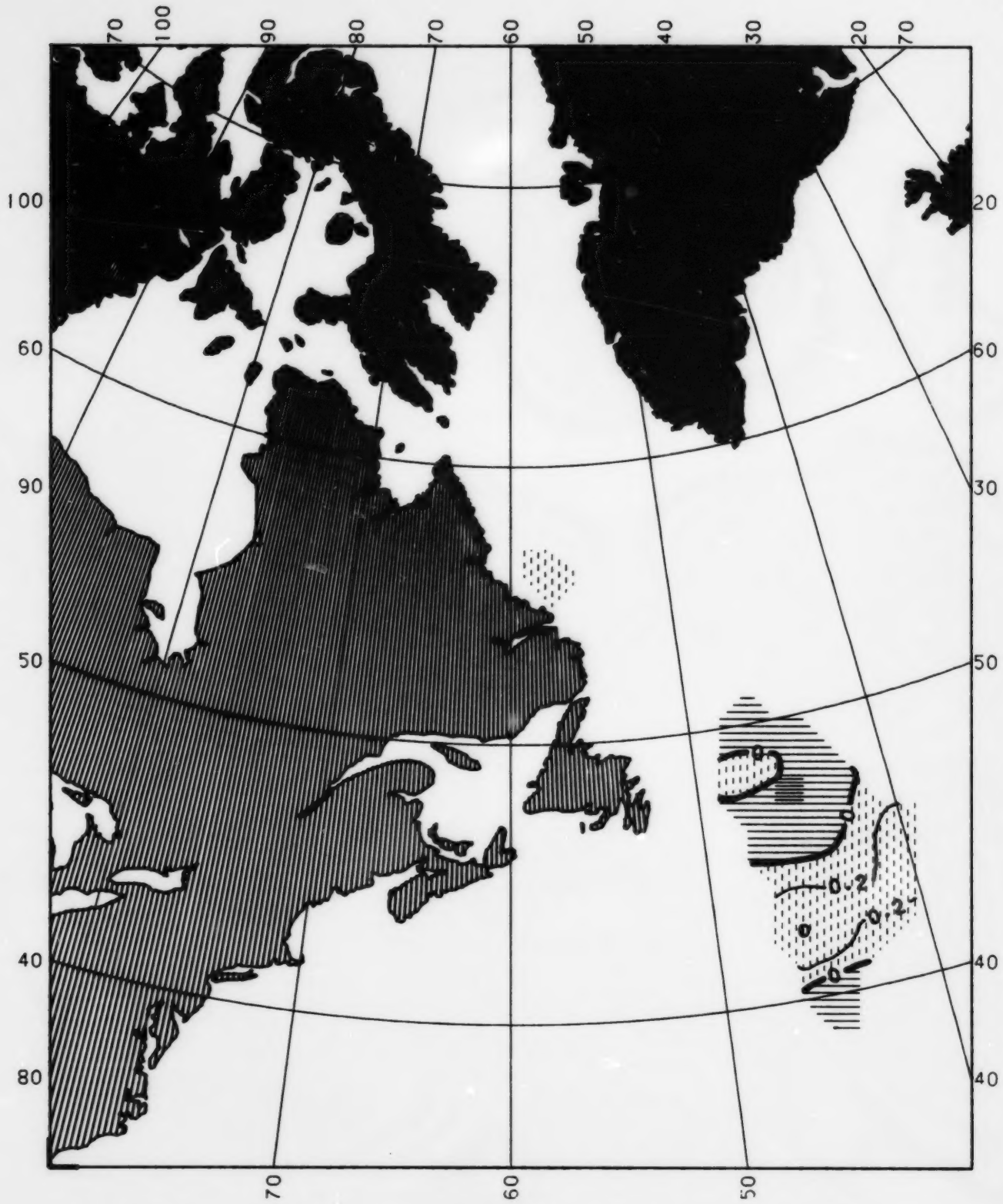

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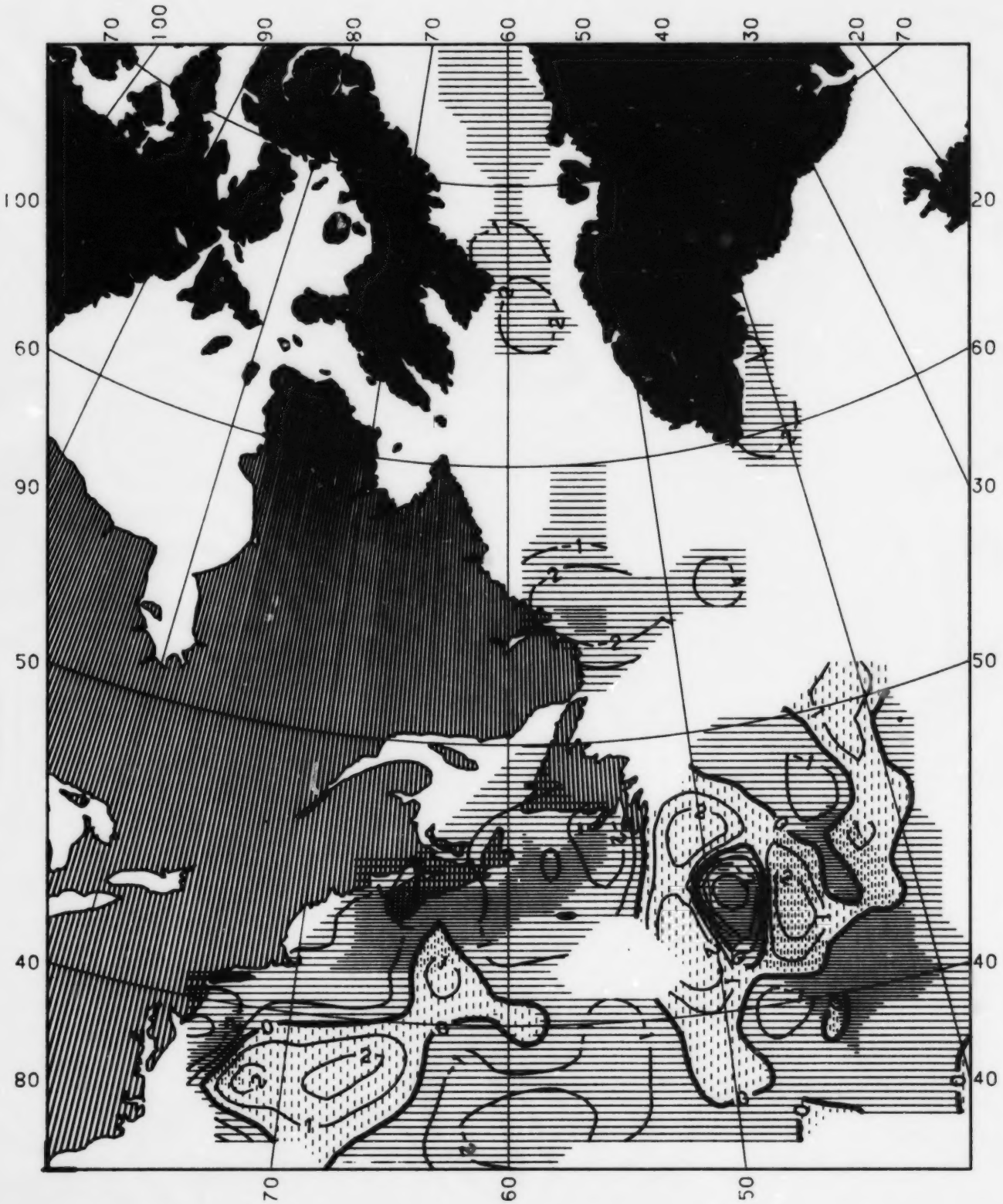

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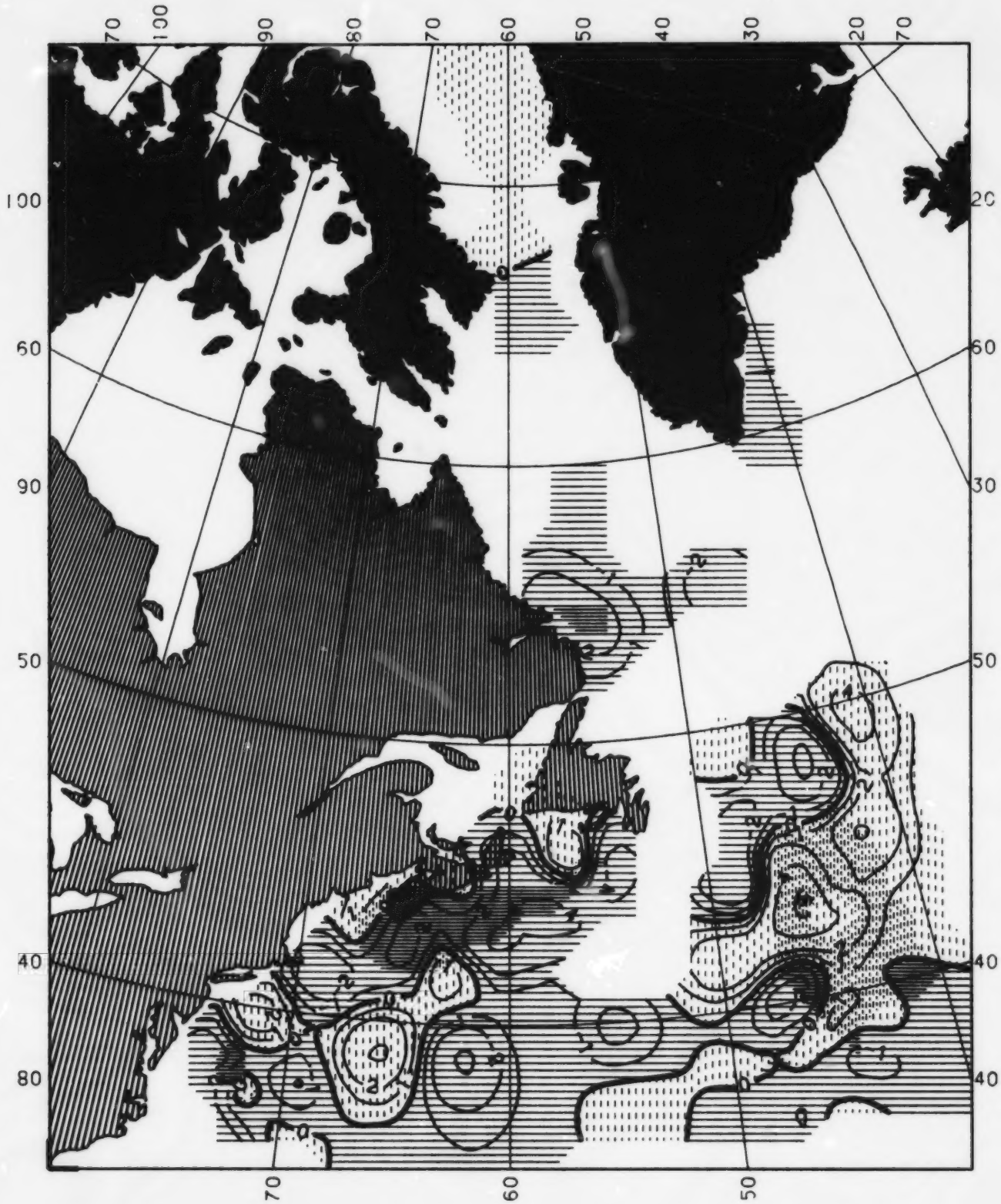

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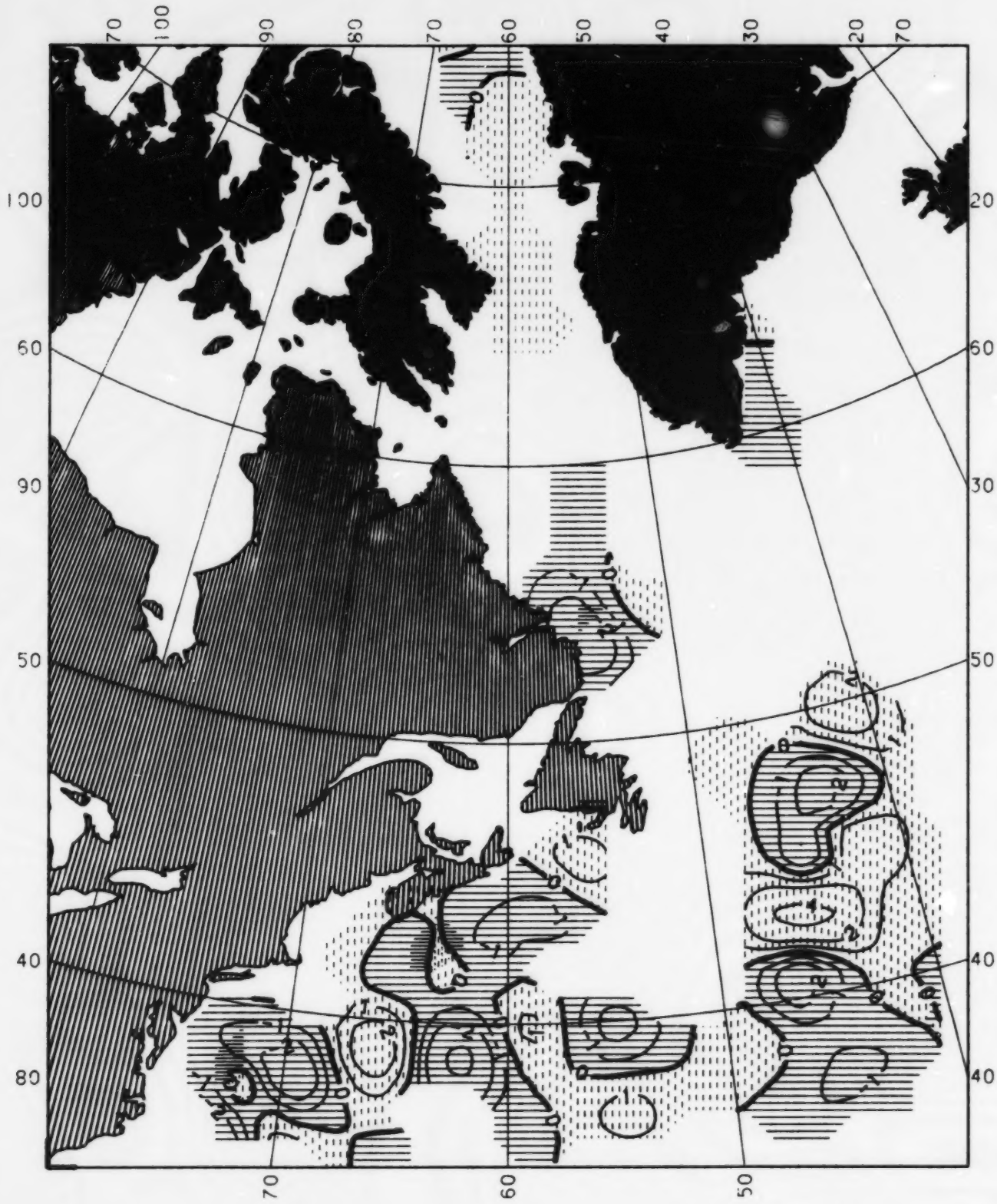

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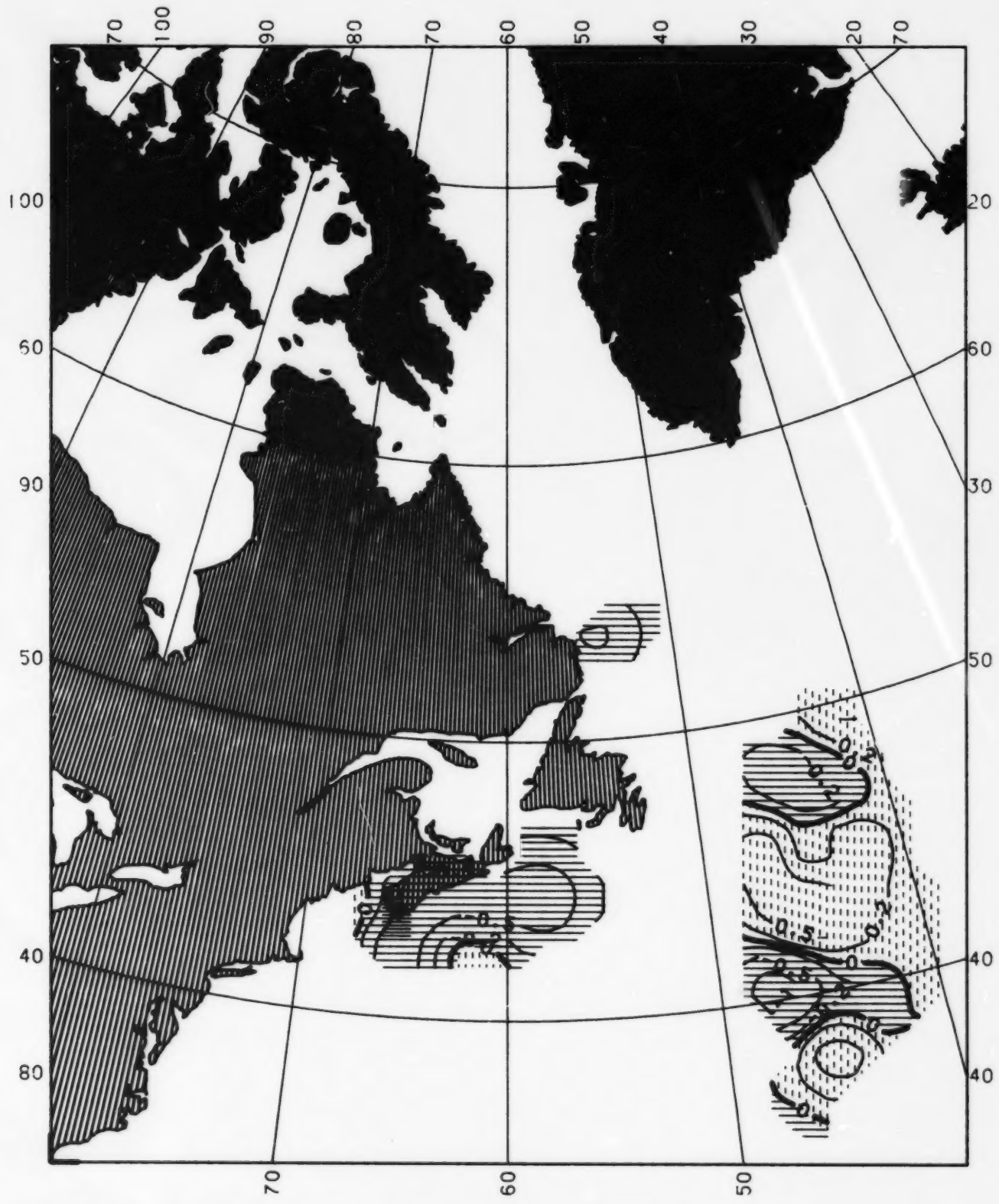
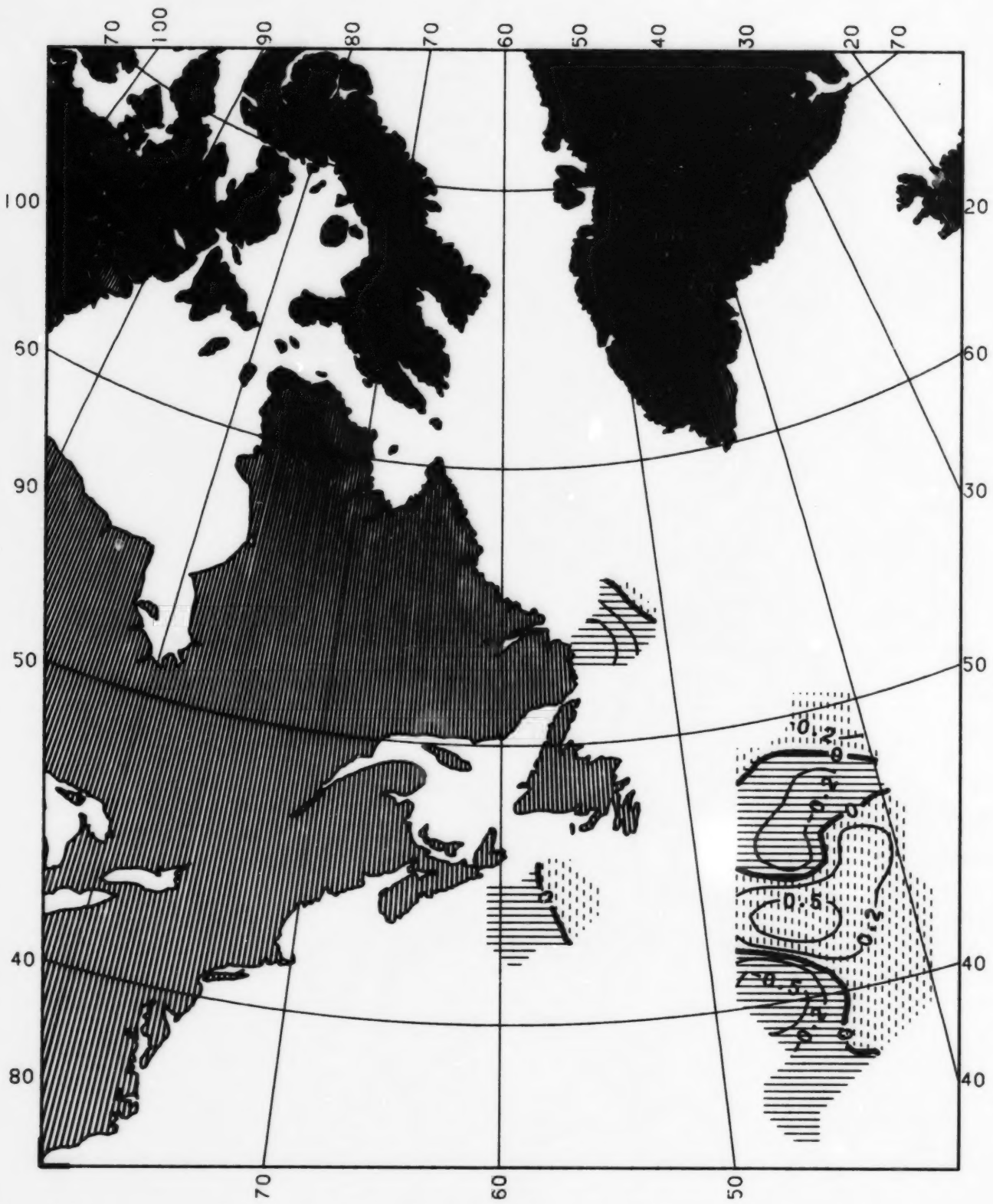


SALINITY ANOMALY IN SUMMER AT 100 M.



SALINITY ANOMALY IN SUMMER AT 250 M.

SALINITY ANOMALY IN SUMMER AT 500 M.